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The EUROPEAN CORN BORER

ITS PRESENT STATUS AND METHODS OF CONTROL

THE EUROPEAN CORN BORER is one of the most injurious plant pests that have ever invaded this country. The farmers of the United States have not seen it at its worst, for the sums that have been spent in the investigation of the insect and in finding ways to keep its numbers down have resulted in methods that have decidedly reduced infestations.

After the corn is cut for feed or silage or after the ears are harvested, the borers can be so completely destroyed as to leave few alive to start another year's infestation. The more thoroughly this is done the greater will be the freedom from injury in the succeeding crop.

This bulletin tells about the habits of the corn borer that make it easy for the farmer to employ protective measures during the winter months and early in the spring. The farm machinery that has been developed to destroy or effectually bury corn borers is also described.

Remember that to accomplish the destruction of the corn borer all remnants of crops that might be infested must be destroyed before May 15, and that one field left uncleaned or one barnyard with stalks still lying on the ground will furnish an abundance of moths for the entire neighborhood.

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THE EUROPEAN CORN BORER: ITS PRESENT STATUS AND METHODS OF CONTROL[1]

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CONTENTS

	Page
History of the corn borer and its known distribution in North America	2
Corn, the favorite host of the corn borer in this country	3
Character of injury to corn caused by the corn borer	7
Character of injury to plants other than corn in the two-generation area	8
Description and seasonal history of the corn borer	10
In the one-generation area	10
In the two-generation area	12
Crop loss caused by the borer	14
In the one-generation area	14
In the two-generation area	14
In Canada	15
In Europe and Asia	15
Natural enemies of the corn borer	16
Native insect parasites	16
Introduced insect parasites	16
Birds	18
Disease	19
Methods of controlling the corn borer	19
Feeding infested plants to livestock	21
Plowing deep and clean	26
Burning infested plants	29
Disking stubble or entire-stalk fields is not effective	33
Corn stubble is an important source of infestation	33
Destroying borers in home gardens	33
Control methods that may be useful under certain conditions	34
Time of planting in the one-generation area	34
Time of planting in the two-generation area	34
Choice of corn varieties	35
Trap crops	35
Ineffective control measures	35
Trap lights	35
Attractive baits	35
Caterpillars often mistaken for the European corn borer	36
The corn ear worm	36
The stalk borer	37
The smartweed borer	38
The southern corn stalk borer	39

THE EUROPEAN CORN BORER [3] is a pest of foreign origin that was first discovered in the United States in the summer of 1917. Since that time the best efforts of Federal and State agricultural authorities have been devoted to the task of retarding its spread and of devising methods for its control.

The results of 16 years' study leave no room for doubt that the corn borer is one of the most injurious plant pests that have invaded this country. Furthermore, unless the recommended measures for its control are strictly and universally adopted in all areas infested by the pest, serious and wide-spread losses to corn and other susceptible crops, similar to those that have occurred in Europe and in Ontario, Canada, are very likely to occur in the United States.

Investigations have shown conclusively that the total eradication of the European corn borer in this country is not practicable. It has been found feasible, nevertheless, through improved farm-clean-up methods and other cultural practices, to reduce the number of the borers in any given area to such an extent that the damage by the insect can be kept below the point of serious commercial loss.

[1] The original edition of this bulletin was written by D. J. Caffrey and L. H. Worthley.

[2] Mr. Caffrey, who was formerly in charge of European corn borer research in the Division of Cereal and Forage Insect Investigations, was transferred to the Division of Truck Crop and Garden Insect Investigations Mar. 1, 1934.

[3] *Pyrausta nubilalis* Hbn.; order Lepidoptera, family Pyralidae, subfamily Pyraustinae.

HISTORY OF THE CORN BORER AND ITS KNOWN DISTRIBUTION IN NORTH AMERICA

When the European corn borer was first reported and identified from North America in 1917, it was found to be causing severe dam-

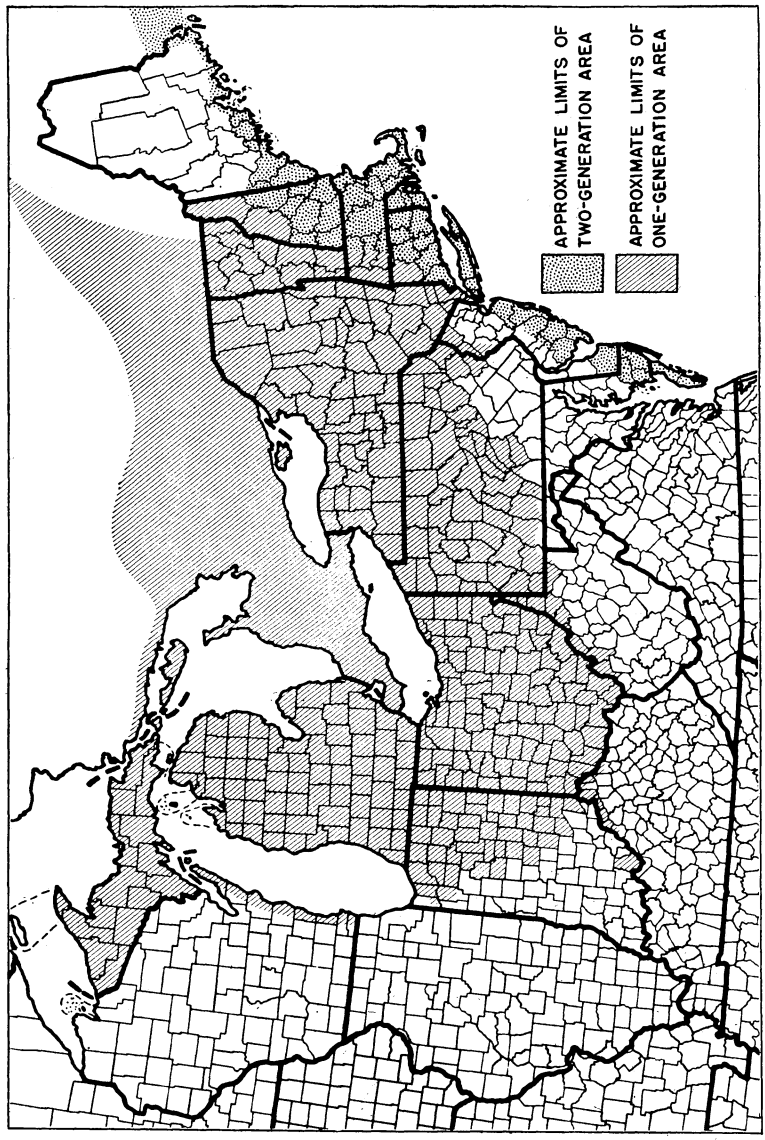

FIGURE 1.—Areas in the United States known to be infested by the European corn borer up to the close of 1934. The approximate limits of the Canadian infestations are also shown.

age to sweet corn in the vicinity of Boston, Mass., and to be present in a district comprising at least 100 square miles.

Subsequently it was learned that as early as 1917 the borer was also present in the vicinity of St. Thomas, Ontario, Canada, and in the districts centering around Schenectady and Silver Creek, N. Y.

The exact date on which this dangerous pest gained entrance to North America is not definitely known, but circumstantial evidence accumulated since its original discovery indicates strongly that broomcorn, imported from Hungary or Italy during the period from 1909 to 1914, was the probable means of entrance. The quarantine inspection service at ports of entry was not authorized by law until 1913, or subsequent to the probable original entry of the corn borer into this country.

Figure 1 shows a total area of about 265,000 square miles infested in the United States by the end of 1934. The limits of the shading on the map indicating the areas covered by the two "strains", the one-generation and the two-generation, have in general followed the boundaries of the counties known to be infested, and it must be understood that there can be no sharp demarcation between the areas occupied by the two strains where they have met and intermingled in the western parts of New England and on Long Island, N. Y. The insect has been found at several isolated points at some distance from the area of general infestation. These isolated infestations have been subjected to intensive clean-up operations.

The corn borer moths are strong fliers, and it is believed that the extension of the infested areas each year is caused principally by flight. Experiments have shown definitely that corn-borer moths are able to fly for a distance of at least 20 miles, and judging from their general habits it is probable that they can and do fly greater distances. Large bodies of water do not check their flight, as the moths have been seen to alight on the surface of the water and again take flight. Experiments have also shown that the moths were able to reach cornfields surrounded by high hills or woodlands. During windy periods flight is usually in the direction of, or with, the wind.

It is also known that the larvae can survive long periods of submersion in fresh or salt water when hidden in cornstalks. This fact, plus the fact that cornstalks are known to have been borne long distances in the currents of rivers, lakes, and the ocean, renders it quite likely that many of the new infestations along the North Atlantic seaboard, in the Great Lakes region, and along the river courses of the present infested area may have had their origin in water-borne infested cornstalks or other infested plant material.

CORN, THE FAVORITE HOST OF THE CORN BORER IN THIS COUNTRY

Corn is infested and injured (figs. 2 and 3) by the larvae, or borers, of the European corn borer to a greater extent than any other crop attacked by the insect in this country. The borer attacks field corn (both dent and flint), sweet corn, pop corn, and corn planted for fodder or silage. From 16 years of experiments and observation, it appears that corn (Indian corn or maize) is the favorite host of the insect in North America, as it is in Europe.

In the one-generation area of the North Central States (fig. 1), corn was practically the only plant that had been injured or infested to any extent on cultivated land by the corn borer up to the end of 1934. A light infestation has been found in some of the more common large-stemmed weeds and grasses growing among the corn or along the margins of badly infested cornfields. Careful examina-

tions under these conditions have revealed the presence of the borer in pigweed (*Amaranthus* spp.), smartweed (*Polygonum* spp.), cocklebur (*Xanthium* spp.), barnyard grass (*Echinochloa crus-galli*), lambs-

FIGURE 2.—Corn borer injury to various plants. Top at left: Larvae and pupae in cornstalks; and young tassel attacked by the insect. Male and female moths drawn on same scale as the corn. Top center: A female moth with cluster of eggs on a section of corn leaf, on a considerably larger scale. Top right: Mature tassel showing typical injuries by caterpillar (the broken tassel stem is often the most noticeable evidence of the presence of the insect during the early summer months). Center: External and internal views of injuries inflicted on two ears of sweet corn. Lower half of the figure: Snap beans, beets, and celery attacked by the borer; cornstalk containing caterpillars; corn stubbles cut away to show how the caterpillars hide themselves in the fall, winter, and early spring months; smartweed, which is a favorite food at times; barnyard grass, which in Massachusetts is often heavily infested; and cocklebur plant, a weed that often serves as a breeding place for the pest.

quarters (*Chenopodium* spp.), foxtail (*Chaetochloa* spp.), panic grass (*Panicum* spp.), and similar plants.

The fact should be emphasized that in the one-generation area these corn-borer infestations in weeds have been confined to infested cornfields or their margins and are usually caused by the borer seeking shelter in such plants. Several native borers very similar in appear-

ance to the European corn borer (p. 36) are found frequently in vegetables, field crops, flowers, shrubs, or weeds, but only rare instances of corn borer infestations in weeds growing at a distance from corn have as yet been observed, although special and extensive examinations have been made to determine this point.

Under conditions of favorable exposure in western New York, a light infestation has been observed in some of the cultivated crops and flowering plants, including broomcorn, soybeans, millet, buckwheat, sorghum, dahlia, and cosmos. The number and variety of weeds and cultivated crops infested by the corn borer in the one-generation area will probably increase in the future unless a general attempt is made, by carrying out the recommended clean-up measures, to reduce the number of corn borers to a point where such borers as survive will be confined for the most part to corn.

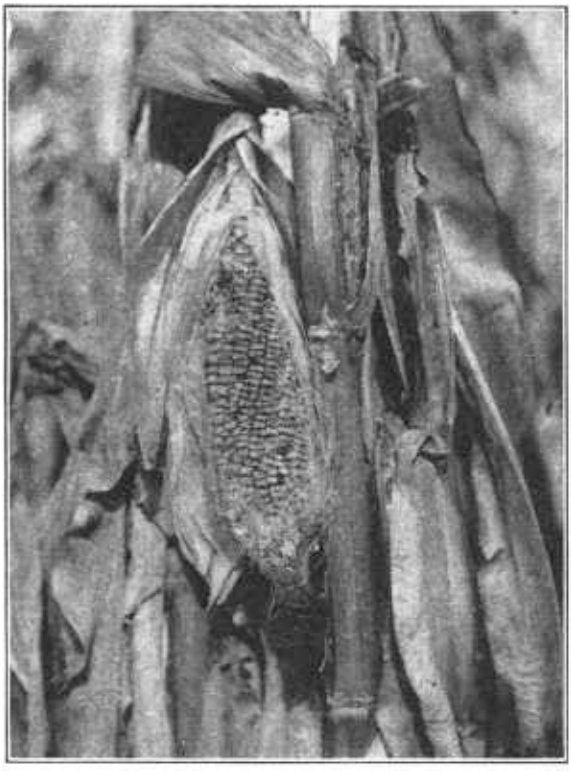

FIGURE 3.—Ear and stalk of dent field corn showing typical injury by the European corn borer.

In the two-generation area (fig. 1) corn is the favorite host of the corn borer, but in this section the pest commonly lays its eggs upon and attacks many other plants, including vegetables, field crops, flowers, and weeds. Rhubarb (fig. 4), beet, celery, bean (especially lima, fig. 5), pepper, oat, millet, dahlia, aster, gladiolus (fig. 6), chrysanthemum (fig. 7), zinnia, cosmos, hollyhock, and many different kinds or species of large-stemmed weeds and grasses are often injured severely by the corn borer in this section. In fact, at the close of 1933 over 200 kinds or species of plants in the two-generation area had been found to be infested. Many of these plants serve as shelter for the borers, rather than as food, and are infested sometimes by the borers which "overflow" from corn and other favorite host plants growing near by.

The reason why so many different kinds of plants are more commonly severely infested by the borer in the two-generation area than where there is only one generation is not definitely known. However, where two generations occur, the moths developing from the overwintering borers begin egg-laying much earlier in the season than in

the one-generation area, and the next brood of moths lays eggs later than do the moths of the single generation. Whereas, therefore, the

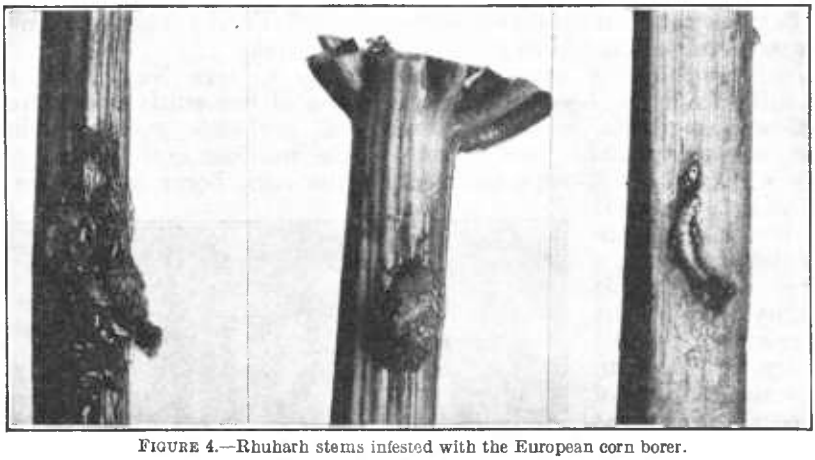

FIGURE 4.—Rhubarb stems infested with the European corn borer.

single-brood moths find corn in abundance and in an attractive condition and do not need to depend on the less desirable plants for

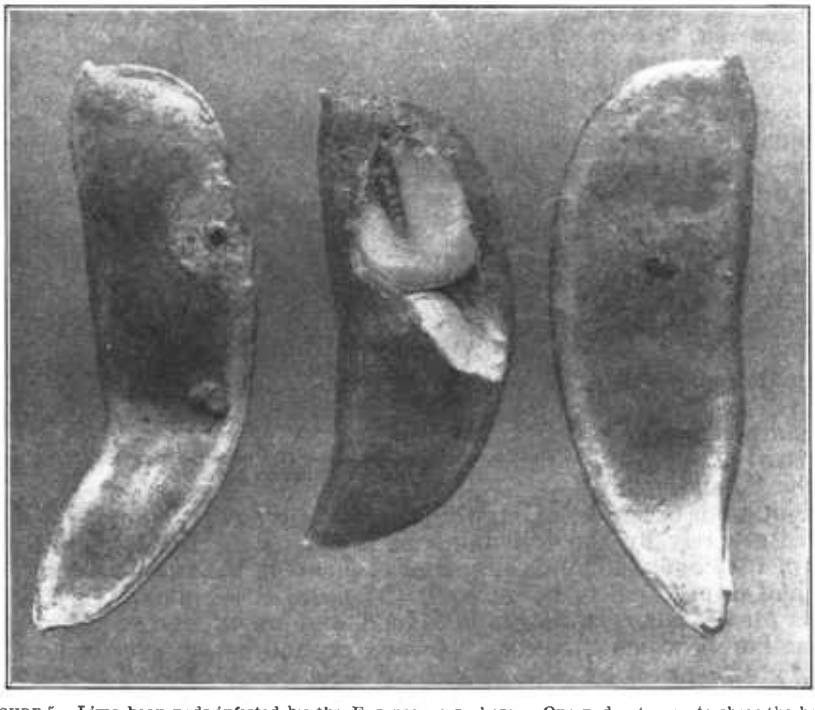

FIGURE 5.—Lima bean pods infested by the European corn borer. One pod cut open to show the borer feeding on the bean within. Borer entrance holes are shown in the other two pods.

food for their larvae, both broods of moths in the two-generation area find many plants attractive when there is often a relatively small acreage of corn in a condition attractive for egg laying.

In some parts of the two-generation area the borers multiply so rapidly that the corn plants become overcrowded with them, and many of the borers are forced to migrate to other plants.

CHARACTER OF INJURY TO CORN CAUSED BY THE CORN BORER

The European corn borer is essentially a boring insect and causes its greatest injury by the tunneling and feeding of the borers within the stalk (fig. 8), ears (fig. 9), tassel, midrib of the leaf, brace roots, stubble, and in fact in practically all parts of the corn plant except the fibrous roots. In addition, they also feed to a slight extent upon the surface of the plant, particularly upon the leaf blades (fig. 10), tassel buds, husks and silks of the ear, and leaf sheaths.

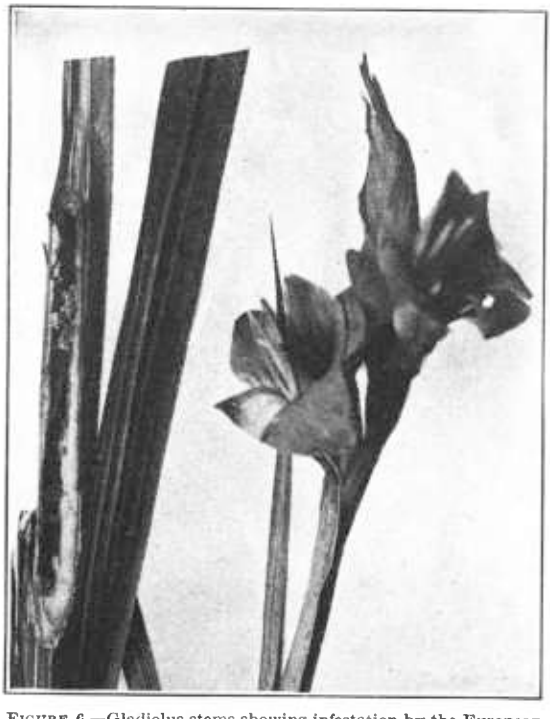

FIGURE 6.—Gladiolus stems showing infestation by the European corn borer.

The character of the injury inflicted depends on the stage of development of the corn plant when attacked and on weather conditions. Usually, however, the newly hatched borers feed for a short period upon the surface of the plant, particularly on the tender leaf blades (fig. 10) or the green silks and husks of partially developed ears. Within a few hours after hatching, many of the borers begin to migrate to various parts of the same plant or to other plants in the vicinity. If the attacked plant is just developing a tassel, some of the small borers enter the tassel buds and feed within, while others feed on the surface of the tassel buds and protect themselves with a slight silken web. Later they tunnel within the tassel stem and its branches, often causing it to break over. These broken tassels (fig. 11), with bunches of sawdustlike "borings" at the breaks, are the most conspicuous signs of corn borer infestation in fields of growing corn, although many of the infested corn plants may not show this particular injury. The borers may continue tunneling downward into the main stalk, or they may leave the upper part of the plant and enter it or neighboring plants at points lower down. Some of the newly hatched borers, instead of feeding upon or within the tassel buds and tassel stalks, enter the stalk directly at some lower point.

The borers usually enter between the leaf sheath and stalk or between the stalk and the base of the partly developed ear (fig. 2), in case the plant has advanced to that stage of development. As they gradually increase in size their tunnels are made larger, and the borers work upward or downward, according to their individual preferences, although the majority work upward. Small holes in the plant (fig. 2) with bunches of sawdustlike borings at or below the holes indicate the section in which the borer is at work.

The tunneling of 1 or 2 borers in a stalk does not always cause appreciable damage; but when several or many are present within the same stalk, as frequently occurs, it becomes reduced to a mere shell and is filled with fragments of the frass or castings of the borers. Such injury may cut off much of the supply of nutriment from the ear and greatly weaken the stalk, which eventually breaks over. It has been found that corn plants suffering from severe corn-borer injury ripen much earlier than uninjured or slightly injured plants.

FIGURE 7.—Injury to stem and flower of greenhouse chrysanthemum done by the European corn borer. Stem cut open to show borer within and type of injury to stem and flower head.

At any stage of their development the borers may enter the ear directly at its tip, base, or side; or may enter it indirectly through the short stem or shank by which the ear is attached to the stalk, in which case this stem is frequently so weakened by the injury that it breaks over before the ear has completed its development. Ordinarily the ear is entered at its tip (fig. 12) by small borers which feed first upon the silks or the tender portion of the husk, and then work their way down into the cob and grain.

The injury to stalks and ears done by the corn borer may be still further increased by decay, which often follows the work of the borers.

CHARACTER OF INJURY TO PLANTS OTHER THAN CORN IN THE TWO-GENERATION AREA

Mention has been made of the fact that plants other than corn are often severely infested by the corn borer in the two-generation area. *The remarks under this heading therefore apply only in that area.*

The injury to plants other than corn is of the same general character (fig. 2) as that to corn, except that in some instances only particular parts of the plants appear to be preferred for food or shelter.

FIGURE 8.—Hill of sweet corn ruined by the European corn borer. Stalks sectioned to show extensive damage within. There were, on an average, 37 borers per plant in this field.

The stems or stalks of celery, rhubarb (fig. 4), potato, hop, oat, barley, buckwheat, hemp, cotton, dahlia, chrysanthemum (fig. 7), gladiolus (fig. 6), aster, zinnia, cosmos, geranium, and other plants

are entered and tunneled by the borers, and the borers are sometimes found in the fruits or flowers of certain plants, notably tomato, pepper, cotton, hemp, dahlia, chrysanthemum, and gladiolus.

The stems and leaves of beet (fig. 2), Swiss chard, and other plants are preferred by the borers when attacking these plants. The roots of beet are entered occasionally.

In beans the borers are usually found in the stalks, pods (fig. 5), or green beans.

Not only do the borers cause actual loss by their injury to these crops, but there is also the likelihood that such products, when distributed through commerce, may serve as carriers of the pest to new localities.

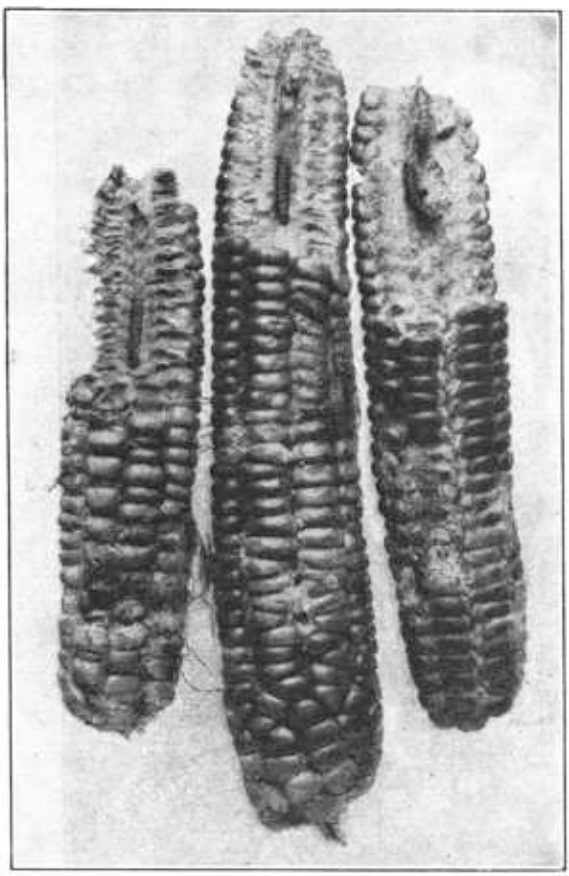

FIGURE 9.—European corn borer injury to grain and cob of flint field corn. Cobs cut open to show borers within. Every stalk and ear in the field from which these ears were harvested was infested.

The presence of the European corn borer in the two-generation area in weeds and wild grasses (fig. 2) is not of itself commercially important, but it affords abundant opportunity for the multiplication and spread of the pest throughout districts where corn is not grown.

DESCRIPTION AND SEASONAL HISTORY OF THE CORN BORER

IN THE ONE-GENERATION AREA

In the one-generation area of the North Central States (fig. 1) the European corn borer passes the winter as a fully grown borer or "worm" inside its tunnel in the stalk, stubble, or ear of corn, or in some weed or other plant material growing close to corn. The presence of the borers may be indicated by small holes on the surface of the infested plants. These holes are usually plugged with the castings of the borers. When these stalks, stubble, etc., are split open, the borers (fig. 2) usually are found within. At this time the borer is nearly an inch long and one-eighth of an inch thick (fig. 13). The head is dark brown or black. The upper surface of the body ranges in color from light brown to dark brown or to pink. Each division of the body bears a row of small dark-brown spots, while

several narrow dark-brown or pink lines extend lengthwise of the body. The underside of the body is flesh colored and is without markings.

As soon as warm weather begins, in April or May, the borers may leave the shelters occupied during the winter and bore into more suitable places to pass the resting stage.

Late in May or early in June the borer cuts a small circular opening from its tunnel to the surface of the plant in order to provide an exit for the future moth. It then closes this hole with a thin partition of silk and retreats into its tunnel to a point near the last feeding or shelter place, where it usually spins a thin cocoon. Inside this cocoon the borer changes into the resting stage, or pupa (fig. 14).

FIGURE 10.—Injury to leaf blades and tassel buds of corn by young corn borers. At this stage of development of the plant, or just before, is the proper time to apply insecticides to sweet corn in the two-generation area.

The pupa, or resting stage, is shuttle-shaped, ranges in color from light brown to dark brown, and is from one-half to five-eighths of an inch in length. After a period of from about 10 to 14 days the skin of the pupa splits, and the moth or adult comes forth. In the North Central States the moth or adult is present in the fields from late in June to early in August, under average weather conditions.

The female moth (fig. 15, at left) has a robust body and measures about an inch from tip to tip of the wings. The general color is variable and includes all shades from pale yellow to light brown. The outer thirds of both the fore wing and the hind wing are usually crossed by two narrow zigzag lines darker than the rest of the wing. The male moth (fig. 15, at right) has a longer, more slender body, is slightly smaller in wing expanse, and is usually much darker than the female. The general color ranges from pale to dark brown, sometimes with a blue tinge. The outer third of the wing is usually crossed by two narrow zigzag streaks of pale yellow, and there are frequently small pale-yellow areas on the fore wing.

The moths of the European corn borer resemble several other kinds or species of moths so closely that it is difficult if not impossible for the average person to distinguish between them.

Soon after emergence the females begin to lay their eggs. They remain quiet during the day, hiding in patches of weeds and grass or underneath the leaves of other plants. During the evening and sometimes throughout the night, when weather conditions are favorable, they fly from plant to plant, laying their eggs in flat, irregularly shaped masses (fig. 16). The number of eggs laid by each female

moth averages about 400, although the number varies greatly, and a maximum of over 1,900 has been observed. The moths live from 10 to 24 days.

There are usually from 15 to 20 eggs in the average egg mass. As many as 162 eggs have been found in a single mass, although eggs deposited singly may be observed. These egg masses are laid principally upon the underside of the corn leaves, although they are sometimes laid on the upper side of the leaf, on the stalk, or on the husk of the ear. Each egg is about half the size of an ordinary pinhead, and in the clusters the eggs overlap like fish scales. By closely examining the under surface of corn leaves it should be possible for any person to find these egg masses where the moths are numerous.

FIGURE 11.—Broken corn tassel showing injury caused by larvae of the European corn borer.

The egg is nearly flat and is white when first laid, but later changes to pale yellow, becoming darker just before the young borer comes out.

The eggs hatch in from 4 to 9 days, depending on weather conditions. The newly hatched borer is about one-sixteenth of an inch long and has a black head and a pale yellow body that bears several rows of small black or brown spots. Occasionally it feeds for a few days upon the surface of the leaf, near its place of hatching, but it soon enters the plant, where it completes most of its development. It may also move to other plants in the vicinity by crawling or by spinning a suspending thread.

During its growth the borer changes its skin, or molts, 5 or 6 times, gradually increasing in size with each change until at last it reaches the stage in which it passes the winter.

In the North Central States most of the borers become nearly full grown by the middle or latter part of August if the weather conditions are normal. The borers continue to feed, or bore, however, at intervals until cold weather stops their activities in October or November. They remain in a dormant condition throughout the winter within their tunnels in the cornstalks, stubble, cobs, or other plant remnants.

IN THE TWO-GENERATION AREA

In the two-generation area (fig. 1) the corn borer has either two complete generations or one complete and one partial generation each year. When weather conditions are unfavorable for the borer, only a partial second generation develops. Favorable weather conditions

produce practically a complete second generation. In this two-generation area the overwintering borers are entering the resting stage (or pupa) during May and early in June. The moths emerge from the

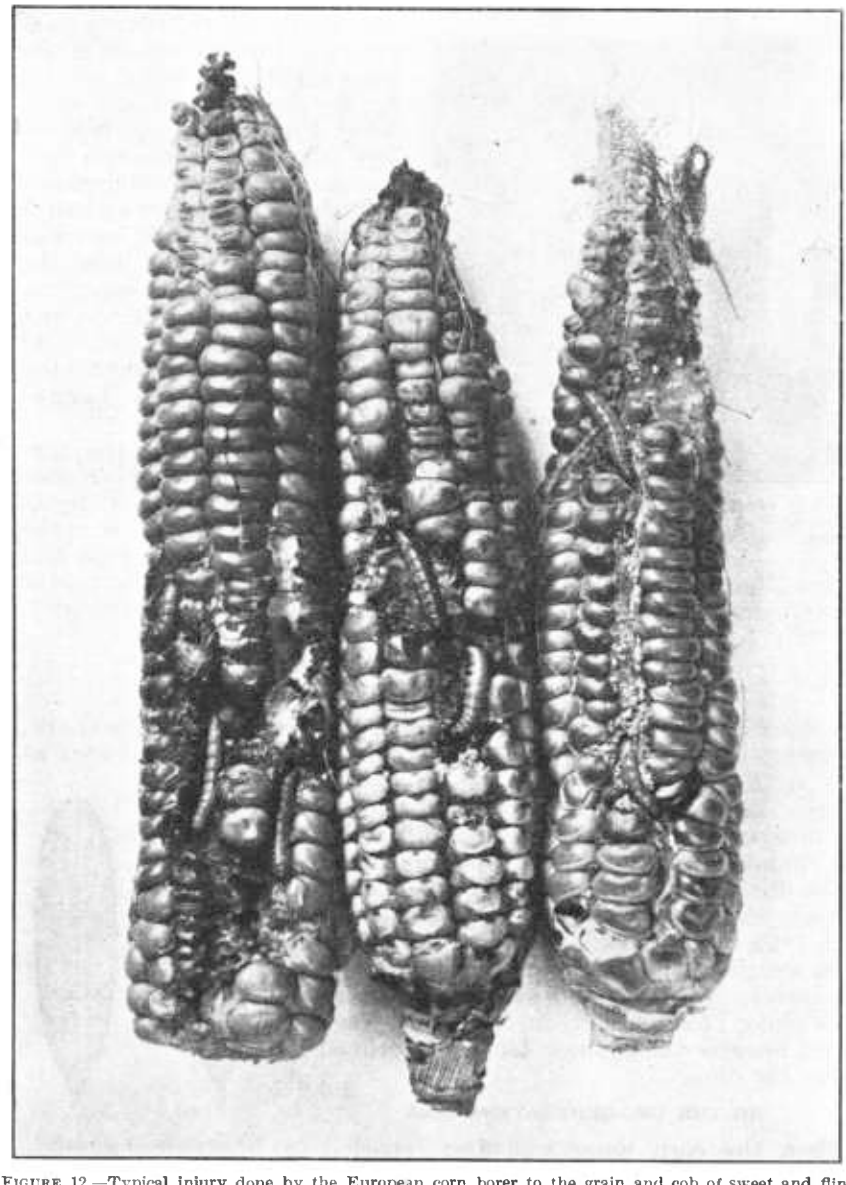

FIGURE 12.—Typical injury done by the European corn borer to the grain and cob of sweet and flint corn. The borers are shown feeding in natural position. The inside of the cobs was also badly tunneled by the borers.

resting stage during June and early in July and lay their eggs during that period. The borers hatching from these eggs are considered to be the first-generation borers. Part of these borers (the percentage depending on weather conditions) become fully grown during the

period extending from late in July to late in August, and enter the resting or pupal stage. The moths emerge from this resting stage during August and early in September and lay their eggs throughout those months. The borers hatching from these eggs constitute the second or overwintering generation, which develops in the same manner as that described for the first-generation borers. They become fully grown before the appearance of cold weather. These second-generation borers, together with such of the first-generation borers as did not transform, pass the winter in a dormant condition within the stalks, stubble, and cobs of corn and in the stems of a great variety of vegetables, flowers, weeds, and large-stemmed grasses.

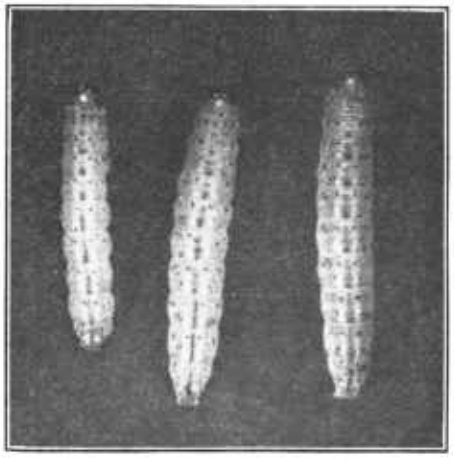

FIGURE 13.—Full-grown larvae of the European corn borer. It is at this stage that the borer passes the winter. Twice natural size

The discussion in the preceding paragraph applies particularly to the seasonal development of the corn borer in the district immediately west and north of Boston, Mass. In the more southern infested areas each stage of development appears a week or more earlier than in the Boston district.

CROP LOSS CAUSED BY THE BORER

IN THE ONE-GENERATION AREA

Serious injury to corn occurred first in 1926 in western New York, northeastern Ohio, and southeastern Michigan, with crop losses as high as 25 and even 40 percent in the most severely infested fields. In these districts and in Pennsylvania there were nearly four times as many borers present as at the same time in 1925. In the one-generation area as a whole there was a yearly increase in the intensity of infestation from 1926 to 1931, with the exception of 1930, when weather conditions were not favorable for the insect. In 1931 the sweet corn in some fields along Lake Ontario in New York was discarded because the canning factories declined to accept the crop.

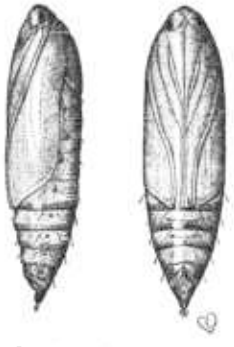

FIGURE 14.—The resting stage, or pupa, of the European corn borer. About twice natural size.

IN THE TWO-GENERATION AREA

When the corn borer was first reported in the vicinity of Boston, in 1917, it was already causing severe damage to sweet corn. The degree of injury increased up to 1922 as the infested area extended, and not only sweet corn but field corn was badly damaged, approximately 20 percent of the ears, on an average, being infested and some small acreages showing an infestation of from 80 to 100 percent of the ears. Many truck and garden crops, also, were damaged. From

this time on through 1926 the degree of infestation decreased owing to unfavorable weather and the enforcement of State clean-up laws.

From 1927 to 1930 there was a new increase in intensity as well as in the extent of the infestation, commercial damage occurring in

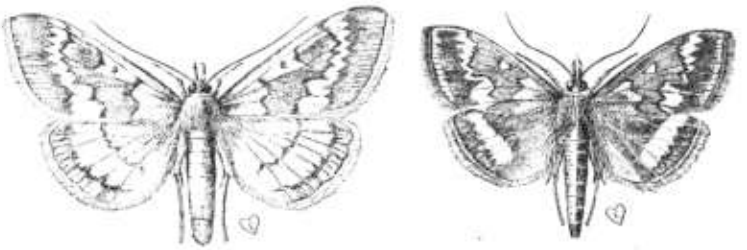

FIGURE 15.—Moth or adult stage of the European corn borer. At left, female moth; at right, male moth. Not quite twice natural size.

southern Massachusetts, Rhode Island, Connecticut, and eastern Long Island, and the infestation covering all of eastern and southern New England and large parts of New Jersey. By 1933 the losses in Connecticut to field corn were in places as high as 56 percent, and some fields of sweet corn were plowed under as a total loss.

Judging from what is known of the insect both in Europe and in Japan, more than two generations annually will occur south of North Carolina and Tennessee if this pest extends its range into that region.

FIGURE 16.—Egg mass of the European corn borer. Slightly enlarged.

IN CANADA

At the close of 1925 the infestation in Ontario, Canada, had become so serious that in counties where the best dent corn in Canada had formerly been grown the corn crop throughout an area of at least 400 square miles was completely ruined. In 1926 in an area of about 1,200 square miles the corn acreage had been reduced to about 10 or 15 percent of that of 1922. Many fields suffered a complete loss of the crop, and losses of 75 percent were common (fig. 17). Less favorable weather for the borer and compulsory clean-up of the fields since 1926 improved conditions from year to year.

IN EUROPE AND ASIA

The European corn borer has long been recognized in Europe and Asia as one of the worst pests attacking corn, millet, hops, hemp, and similar crops. Although it seldom causes severe damage in those Old World areas where all infested corn remnants and other crop remnants are customarily destroyed by burning or plowing or are used for feed or fuel, it causes heavy losses in areas where large quantities of corn remnants are customarily left on the farms from year to year, as is now commonly done in the American Corn Belt.

NATURAL ENEMIES OF THE CORN BORER

NATIVE INSECT PARASITES

Although quite a variety of native natural enemies of the European corn borer have been recorded from this country, they do not usually attack the pest in any important numbers, and, from present indications, cannot be relied on to hold the corn borer in check.

Extensive studies of the native insect parasites of the corn borer in the one-generation area (fig. 1) of the North Central States have shown that only a fraction of 1 percent of the borers were being destroyed by them. In a similar manner it has been found that less than 1 percent of the borers, on an average, were killed by native

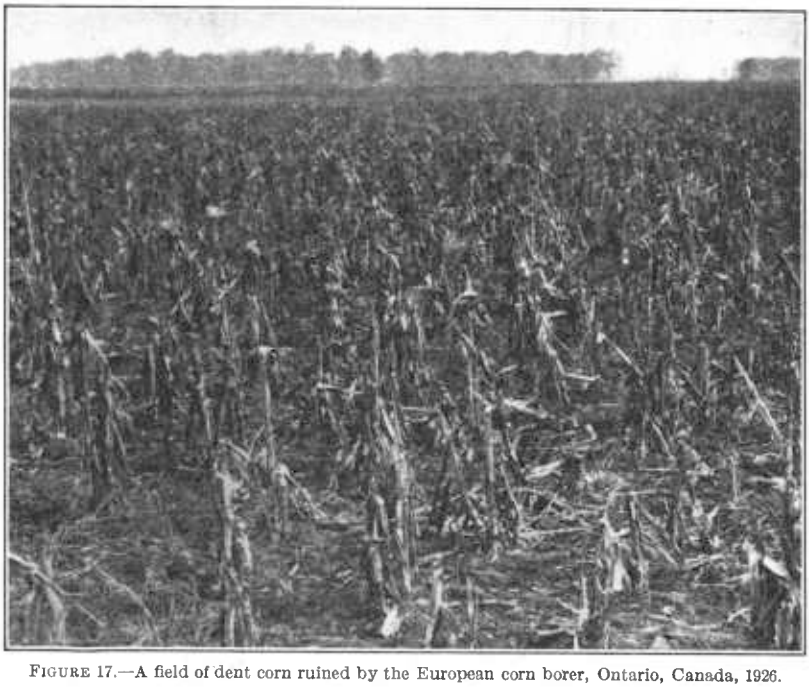

FIGURE 17.—A field of dent corn ruined by the European corn borer, Ontario, Canada, 1926.

parasites in the two-generation area of infestation, although 24 different kinds of parasites were attacking the corn borer in that area.

INTRODUCED INSECT PARASITES

Since the native insect enemies of the corn borer have been of little consequence, it seemed important to investigate the foreign parasites that were preying upon the corn borer in its native homes, particularly in France, Italy, Belgium, and Hungary, and in various countries of the Orient. As a first step, however, it was necessary to make careful studies of such parasites in the countries mentioned. These studies revealed several kinds of parasites that were helping to check the ravages of the pest. After it was determined that none of them could by any possibility become harmful to plants, they were sent to the United States and liberated (fig. 18) close to cornfields, or infested plants, where the corn borer was most numerous. Special precau-

tions were taken, of course, to prevent the introduction with them of natural enemies of the parasites (known as hyperparasites).

The importation of parasites from Europe and from the Orient was supplemented by extensive breeding work under laboratory conditions in this country, as a result of which these imported parasites were greatly increased in numbers before being liberated in infested fields.

At the close of the season in 1933 nearly 3½ million of these imported parasites had been liberated in Michigan, Indiana, Ohio, Pennsylvania, and New York, in the one-generation area. Sixteen distinct kinds or species were released at favorable points from the eastern

FIGURE 18.—Liberating foreign parasites of the European corn borer.

end of Lake Ontario to the limits of borer abundance in northeastern Indiana, and southerly in Ohio as far as the abundance of the borer would justify. Three of these species (*Lydella grisescens* Meig., *Inareolata punctoria* Rom., and *Chelonus annulipes* Wesm.) are well established, but according to definite field records made in 1933 they were killing less than 1 percent of the borers in the immediate vicinity of the liberation points, and slight parasitization occurred at distances of from one-half to 2½ miles. One of these parasites, *I. punctoria* (fig. 19), is now multiplying to an encouraging extent. Note in the illustration the long egg-laying organ of this parasite. Two additional species of parasites have shown encouraging indications to date.

In the two-generation area, work similar to that described for the one-generation area has resulted in liberating approximately 2 million of these imported parasites, comprising 20 different kinds or species,

up to the close of 1933. In this area, at one of the oldest parasite-liberation points in eastern Massachusetts, at least 6 of these species (*Inareolata punctoria* Rom., *Lydella grisescens* Mcig., *Zenillia mitis* Meig., *Zenillia roseanae* B. and B., *Chelonus annulipes* Wesm., and *Phaeogenes nigridens* Wesm.) are known to have survived and to have become established in highly encouraging numbers. Approximately 15 percent of the overwintering brood of corn borers are being killed by these imported parasites within a radius of 7 miles, and approximately 10 percent within a radius of 11 miles. Other more recent liberations have shown similar encouraging results. Approximately 24 percent of the summer generation of corn borers were killed by parasites in 1932 within a radius of 7 miles and 13 percent within 11 miles from the oldest liberation point.

THE PARASITES CANNOT HARM PLANTS

It should be understood that none of these parasites can, through any chance, become harmful to plant growth, as they are parasitic exclusively on insects and never depend on plants for food.

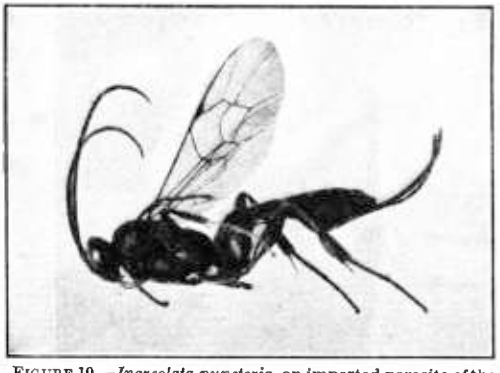

FIGURE 19.—*Inareolata punctoria*, an imported parasite of the European corn borer. A female, about 5 times natural size.

THE PARASITES CANNOT BE DEPENDED ON TO CONTROL THE BORER

Although strenuous efforts have been made to import and establish parasites in the North American areas infested by the corn borer it is by no means certain that they will prove to be effective aids in control. Even with the best of success, several years may elapse before any important effect can be expected. In the meantime every effort should be made to control the corn borer by the practical methods discussed in this bulletin.

BIRDS

With the exception of feeding by woodpeckers in some localities, birds are not known to have an important influence in reducing the numbers of the corn borer in the infested areas of the United States. In some of the large cornfields of the one-generation area and in many of the small garden patches of the two-generation area, the downy woodpecker (*Dryobates pubescens* L.) has been known to remove and destroy from 17 to 95 percent of the borers in the cornstalks and other host or shelter plants. In the winter of 1932–33 woodpeckers destroyed 30 percent, on an average, of the borers in 20 cornfields examined in Ohio and Indiana.

Robins, grackles, blackbirds, starlings, crows, and Mongolian pheasants also are known to feed on the corn borer. Careful observa-

tions in connection with plowing experiments in Ohio, in cooperation with State authorities, showed that robins and other birds were devouring at least 15 percent of the borers that had crawled back to the soil surface after infested cornstalks had been plowed under. The Canadian authorities report that crows removed and devoured about 25 percent of the corn borers from broken-over cornstalks in certain badly infested fields of Essex and Kent Counties, Ontario, during the winter and spring of 1926–27.

Various insect predators, spiders, mites, rodents, and skunks have been observed preying on the corn borer in restricted instances or localities, but to date none of these natural enemies, individually or collectively, have markedly affected the abundance of the corn borer.

DISEASE

The corn borer is comparatively free from attack by disease. However, in 1931 investigations were started with a fungus, *Beauveria bassiana* (Bals.) Vuill. which was known to attack the borer in the Orient. Experiments to date have shown that the corn borer is very susceptible to this disease. Spores of the disease were dispersed in test spots throughout corn borer-infested districts, and a few borers killed by the disease have been found, indicating the possibility that this fungus may become an aid to the natural control of the pest.

METHODS OF CONTROLLING THE CORN BORER

Sixteen years of experience in fighting the European corn borer have shown that the pest may be effectively controlled by utilizing or destroying all parts of infested plants each year before the insects develop from the borer stage into the moth or adult stage. Under practical farm conditions this means that all infested plants must be disposed of principally through any one of the following methods, or by a combination of such methods: (1) Feeding to livestock direct or as silage, or as finely cut or finely shredded feed; (2) plowing under deeply and cleanly; and (3) burning completely.

In presenting the following information on methods of controlling the corn borer, attention is again directed to the point that the habits of the insect in the one-generation area differ in some important respects from its habits in the two-generation area. In the one-generation area corn is practically the only plant directly attacked by the corn borer, and, therefore, the main control effort should be directed against corn, whereas in the two-generation area the corn borer attacks, in addition to corn, such a great variety of vegetables, field crops, flowers, and large-stemmed weeds and grasses that the remnants of these additional plants must be included in farm disposal or clean-up operations. Particularly important, in the two-generation area, are the large areas of weeds growing in waste or unoccupied lands (fig. 20). Such areas must be cleaned up by burning while the plants are dry or by the use of weed killers while the plants are in a green succulent condition. In the one-generation area the corn borer develops only a single brood each year, whereas in the two-generation area there are two broods of the borer per year, and the insect begins its activities earlier in the season and continues them later than in the one-generation area.

Experience with corn borer conditions has shown the desirability, whenever agricultural conditions permit, of disposing of infested cornstalks and other infested plant residues in the fall, especially in fields, gardens, or weed areas which cannot be plowed or otherwise handled effectively in the spring. This applies particularly to fields in which the rotation calls for seeding small grains in the spring and in which the character of the soil is such that it cannot be successfully prepared for small grains or other crops by spring plowing.

Since the corn borer develops into the flying and egg-laying stage late in the spring or early in the summer, it is plain that, in order to prevent the multiplication of the pest, all infested corn plants and corn

FIGURE 20.—Mixed weed growth, mostly barnyard grass and pigweed, in the two-generation area of the European corn borer, on land formerly cultivated. This tract averaged 84 corn borers per square yard in 1922.

remnants should be disposed of before that time. For safety such disposal should be made before May 15 of each year.

Although many of the foregoing recommendations require a radical departure from present farm practice, such changes are necessary under conditions of serious infestation if the pest is to be controlled.

Control of the corn borer is dependent on a community-wide effort because the moths can fly from field to field and thus spread an infestation long distances. The moths emerging from a single uncleaned, or poorly cleaned, infested field can reinfest many other fields that have been properly cleaned up.

In summarizing the general control methods it should be emphasized that the particular method adopted is optional, so long as the infested plants and the crop remnants are disposed of by feeding to livestock, or by plowing clean, or by burning clean, or by any other method that kills the borers contained in the remnants.

Each field presents a separate problem, and clean-up methods will naturally vary according to the type of farming practice used.

FEEDING INFESTED PLANTS TO LIVESTOCK

The feeding of infested plants to livestock is one of the most effective methods of fighting the corn borer and is also a most desirable farm practice. The food value of the fodder is not noticeably injured by the corn borer except in cases of severe infestation. Infested corn plants may be fed as silage, or direct from the field, or in the form of finely shredded or finely cut fodder. When properly carried out, any of these methods of disposal results in the destruction of nearly all of the borers contained in the plants.

To obtain best results with the silo, under corn borer conditions, the infested plants should be cut as close to the ground and as early

FIGURE 21.—Corn binder with low-cutting attachment at work in a field infested by the corn borer. Such low cutting, if cleanly performed, results in practically 100 percent of the borers being removed from the field in the fodder or being placed in the shock, where they will be destroyed in the spring clean-up. (Illustration from Bureau of Agricultural Engineering.)

in the season as possible. Any borers that escape the silage cutter are destroyed in the silo.

Infested cornstalks must be cut into pieces not longer than one-half inch in order that practically all the borers may be killed. The precaution is particularly important in instances where the silage is not placed directly in the silo or is not fed soon after it is cut.

The use of special, low-cutting attachments for corn binders (fig. 21), which are now readily obtainable from some of the larger implement manufacturers, is strongly recommended. Experiments have shown that when cornstalks are cut about the middle of September at least 3 percent of the borers are left in stubble 3 inches high, and at least 7 percent are left in 6-inch stubble. In general, the number of borers living in the stalk (fig. 22) below any given height triples between the middle of September and the first week of November, as the borers move down through the stalk toward winter quarters. This is especially true in the one-generation area.

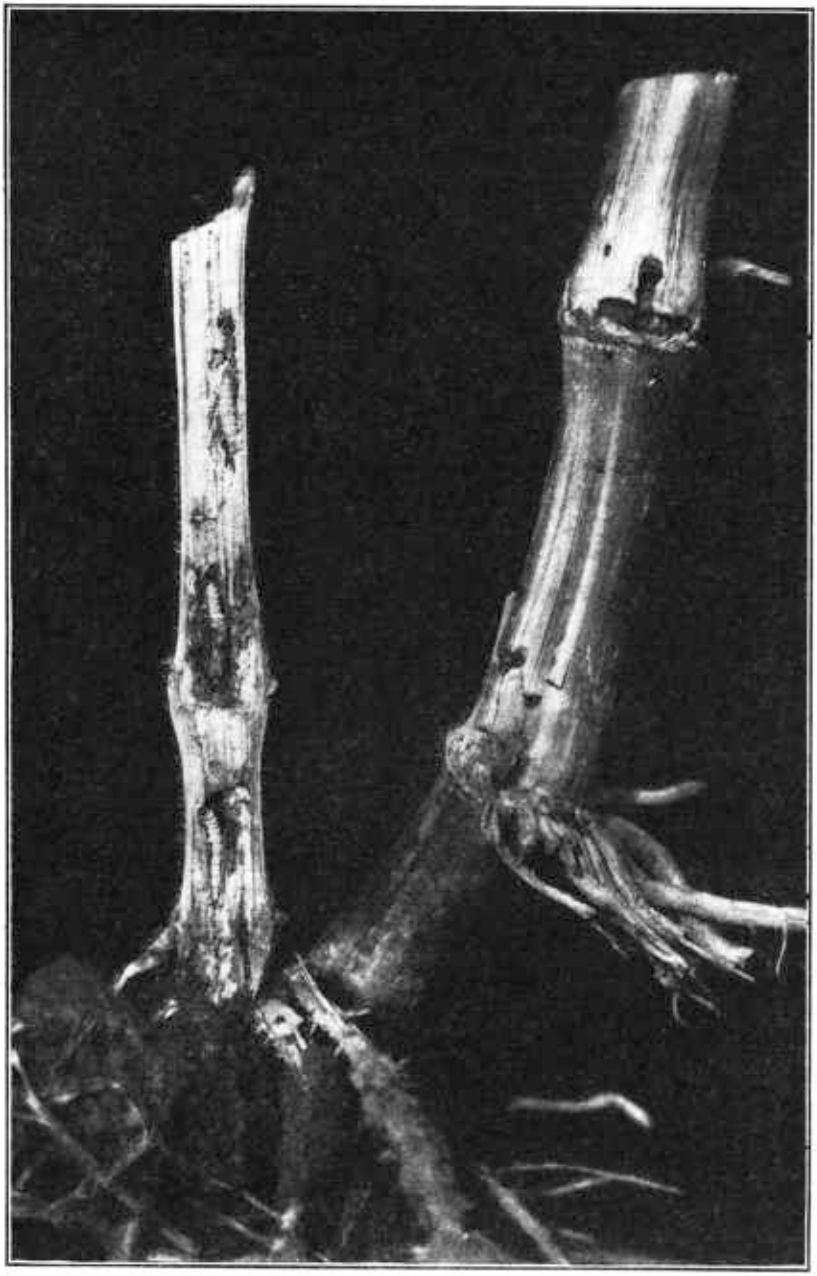

FIGURE 22.—Stubs showing corn borers concentrating near the ground level. One stub is cut open to show the borers within; the other shows the entrance holes made by the borers. This picture illustrates the necessity for cutting cornstalks close to the ground.

A home-made sled harvester has recently been developed, in cooperation with the Bureau of Agricultural Engineering, which effectively cuts at the ground level the stalks intended for silage or fodder. This implement is particularly adaptable to acreages too large for hand-cutting and too small to warrant the purchase of a corn binder with low-cutting attachment.

It is plain that where cutting is the accepted farm practice, the corn should be cut as low and as early as possible. Such low cutting also helps in doing a clean job of plowing later on, and facilitates any other clean-up methods used.

In actual practice the use of short-handled, heavy hoes has been found effective and practicable in many instances where the corn is to be cut by hand. By this method the corn can be cut at, or very

FIGURE 23.—A common source of infestation by the European corn borer: Remains of whole cornstalks fed direct to livestock in pasture and feed lot. These remnants should be raked into piles or windrows and burned.

near, the surface of the ground. The use of hoes for cutting corn has come into increasing favor with farmers, particularly in the smaller fields, where remarkably good jobs have been performed with hoes.

FEEDING DIRECT FROM THE FIELD

When infested cornstalks are fed direct (fig. 23) without previous cutting or shredding, the uneaten parts should be collected and destroyed, preferably by burning, unless they are trampled completely by livestock and thoroughly mixed with the manure of the feed lot.

It is dangerous to allow large quantities of cornstalks to accumulate in barnyards and feed lots (fig. 24) unless they are treated, before May 15 of each year, in the way described in the preceding paragraph. Examinations of cornstalks gathered from barnyards and from the

surface of manure piles on typical farms have shown as many as 256 borers per 1,000 linear feet of stalk. It is apparent that such stalks may constitute an important source of corn borer infestation the following season. No living borers were found in throughly trampled cornstalks or in finely cut or finely shredded corn fodder that had been used for feed or bedding.

EFFECT OF EMBEDDING OR TRAMPLING INFESTED CORNSTALKS IN MANURE

Experiments and observations on infested farms have shown in general that many corn borers survive in cornstalks placed in the ordinary farm manure pile and migrate in large numbers from the piles to seek shelter in surrounding objects. It is therefore strongly recommended that farmers avoid placing infested material in manure piles, that all manure from piles containing infested material be cleanly

FIGURE 24.—A barnyard feed lot that was not sufficiently trampled by livestock. Approximately 15,000 exposed stalks containing nearly 39,000 corn borers. All dry parts of such stalks should be collected and burned, unless completely trampled by animals and thoroughly mixed with the manure.

plowed under early in the spring before larvae begin to migrate in large numbers, and that all plant remnants be removed from barnyards and destroyed or buried.

The number of borers that survive in properly handled feed lots was observed to be so small that any treatment of the stalks in addition to their being trampled by animals is believed to be unnecessary. It is essential, however, that the trampling be thoroughly done and that no dry or unbroken sections of cornstalks be left on the surface of the feed lot. When all plant remnants are thoroughly mixed with manure by trampling, no other treatment need be given. The time of trampling seems unimportant, except that this should be completed before the emergence of moths. If the stalks in feed lots have been insufficiently trampled and still contain living borers, they should be completely plowed under before May 15.

It should be emphasized that under ordinary farm conditions the large uneaten parts of corn fodder should not be put in the manure unless they can be completely trampled in by livestock.

HUSKER-SHREDDER MACHINES ARE VERY EFFECTIVE IN KILLING BORERS

Shredding or cutting corn fodder into fine pieces, as is ordinarily done by husking and shredding machines, kills from 95 to 98 percent of the borers and renders the fodder more acceptable to livestock. This result was obtained in tests with several types of husking machines, commonly termed "shredders", equipped with shredder heads or cutter heads, or with combination shredder and cutter heads. The effectiveness of the machines was increased where special care was taken to apply sufficient pressure on the snapping rolls to produce a crushing effect and prevent long pieces of the fodder from being whirled through the head without being finely cut or shredded. Also, the speed recommended by the manufacturer should be maintained, and the machine should be fed evenly. Department of Agriculture Farmers' Bulletin 1662, entitled "Husker-Shredders in Corn-Borer Control", contains many suggestions and explanatory illustrations regarding the operation of husker-shredders under corn borer conditions.

It has been found that most of the borers that escaped death in the machine perish during the process of storing the shredded material, feeding it to livestock, and using the residue as bedding, which is finally trampled into the manure, in general practice.

This method of disposing of fodder is strongly recommended, and its use in the corn borer territory should be greatly extended.

Inasmuch as many live borers may drop from this machine directly to the ground or pass through with the shelled corn, not only is it necessary to clean up carefully around the machine, but it is very essential that all remaining trash be disposed of properly. Feed the shelled corn and fine trash to chickens or hogs. Burn all the rest of the trash gathered from around the machine after the shredding operation is completed; do not put such trash in the mow.

THE CUTTING BOX IS EFFECTIVE IF ADJUSTED PROPERLY

The cutting box has proved effective in killing borers contained in cornstalks, if adjusted so as to cut the stalks in pieces not more than one-half inch long. Ordinary adjustments that cut stalks into pieces from 1 to 4 inches or more in length do not kill many borers and should not be used.

FEED GRINDERS AND FODDER MILLS OR MEALERS ARE EFFECTIVE

Machines that grind roughage into a mealy consistence are popular with many feeders who want to feed roughage in its most edible form and who wish to control the feed content by using a combination of hay, cornstalks, or other roughage, and grain ingredients. These machines are ideal corn borer weapons when the roughage is ground fine enough to destroy the borers. For corn borer control their use is practical and economical. Some farmers who have tractors may be interested in owning one of these mealers cooperatively with their neighbors.

Be sure to clean up properly around the machine after the grinding operation is completed. Unground trash lying around the machine or scattered between the mow and the grinder may contain live borers.

PLOWING DEEP AND CLEAN

Clean plowing under of infested cornstalks, stubble, and other corn remnants is a very effective method of corn-borer control. This method is limited to soils that are in a condition to permit clean plowing and the preparation of a satisfactory seed bed before the corn borer moths emerge.

Effective plowing, from the standpoint of corn-borer control, depends on turning under the corn remnants and other trash so completely that none of it remains upon the soil surface. It is essential also that the material plowed under should not be dragged to the soil surface by later cultivation before the moths emerge and that the

FIGURE 25.—European corn borer in a small piece of cornstalk on a plowed field. This fragment (natural size) illustrates the necessity for clean plowing.

soil surface should be cultivated or pulverized to close all large cracks and crevices.

The plowing-under of infested material does not of itself kill the borers. Most of the borers crawl up to the soil surface sooner or later. Where the plowing has been done in a clean manner, however, they cannot find any shelter and soon perish as a result of exposure to the weather, or to natural enemies, which include birds, ants, ground beetles, and various insect parasites and predators. If, on the other hand, the plowing has not been done cleanly these borers upon reaching the soil surface bore into any fragments of a corn plant (fig. 25), or weed that may be left on the surface, and with this protection they are able to complete their development to the moth stage.

The choice of the plow and attachments, and the previous treatment, if any, of the stalks or stubble can be left to the judgment and experience of the farmer, provided it is kept in mind that the stalks,

stubble, and other material must be turned under cleanly and not brought to the soil surface by later cultivation.

The depth of plowing for corn borer control is not important, *provided all infested material is covered completely to such a depth that it will not again be brought to the soil surface by later cultivation or weathering,* to act as a shelter for the borers crawling on the surface. In order to insure proper coverage, however, and to reduce the possibility of the plowed-under material being again dragged to the surface, plowing to a depth of at least 6 inches should be adopted if soil conditions permit.

The time of plowing is not important as far as the actual destruction of the corn borer is concerned. For instance, if the stalks are plowed under late in the summer, or early in the fall, or in the spring, most of the borers contained in the stalks crawl to the soil surface soon after the plowing. If the stalks are plowed under late in the fall most of the borers remain inactive in the stalks all through the winter and then crawl to the soil surface after the soil warms up the following April or May. In either case it is important that they find no refuse on the surface in which to hide. Where soil conditions permit fall plowing, the necessity for deep and clean plowing is particularly important as a safeguard against erosion and the frost-heaving of material previously plowed under which sometimes results from shallow plowing under certain soil and weather conditions.

AVERAGE PLOWING METHODS MUST BE IMPROVED

To be effective as a means of corn-borer control, the plowing methods now commonly used in many localities infested by the corn borer should be improved. Poor or ordinary plowing allows many pieces of cornstalks, stubble, husks, weeds, leaves, etc., to remain on the soil surface, thus providing shelter for many of the borers that crawl to the surface after being plowed under. This allows them to change into moths and multiply. For this reason either poor or ordinary plowing not only does not control the corn borer but in many respects is worse than no effort whatever, because a poorly plowed field (fig. 26) creates a condition that is difficult and expensive to clean up by other methods.

The skill of the farmer in doing a good job of plowing is as important, within reasonable limits, as the size or the type of plow used. Under favorable soil conditions 14-inch-bottom plows equipped with attachments for covering trash give good results when properly adjusted. Specially designed 16-inch- and 18-inch-bottom plows, now on the market, are well adapted for clean plowing and give good results even when used in standing cornstalks or high stubble. Field experiments with these plows showed that when they are equipped with a rolling colter of proper size, a jointer, and a chain, or with the covering wires, as hereafter described (fig. 27), practically all standing cornstalks and trash can be covered without previous treatment. With such equipment the stalks and trash can be turned to the bottom of the furrow so completely that the land can later be prepared for other crops without dragging the turned-under material to the surface.

An effective plow attachment of three wires to aid in turning under trash is shown in figure 27. A no. 9 galvanized wire gives good results. The wires should be about 12 feet long, attached as shown in the illustration, with the outer ends left loose. In operation the loose ends are caught by the furrow slice as it is turned over. In this

FIGURE 26.—A poor job of plowing. This type of plowing does not control the European corn borer, as the stalks left on the surface provide shelter for the borers that crawl to the surface after being plowed under.

FIGURE 27.—An effective use of three wires to aid in turning under cornstalks and other trash. The wires are about 12 feet long and the ends are left trailing.

manner the wires are held tightly to the top of the furrow sliee by the weight of the soil on the buried ends of the wires, and this turns all trash to the bottom of the furrow.

The Bureau of Agrieultural Engineering has developed a trash guide and a furrow hook for attaehment to ordinary plows (fig. 28) that in all tests to date, under widely varying field eonditions, have given a very thorough and deep eoverage to heavy growths of eornstalks, high stubble, and other plant refuse.

If the available equipment is not suffieient for plowing entire eornstalks or high stubble eompletely under, the stalks or stubble should be eut at the ground level, raked into windrows or piles, and burned

FIGURE 28.—Clean plowing with the aid of trash guides and furrow hooks. These aids to clean plowing can be easily made and attached to existing plowing equipment. (Photograph by Bureau of Agricultural Engineering.)

as eleanly as possible, or some other effeetive treatment should be used. Any remaining parts may then be plowed under entirely.

Cireular 132, issued by the United States Department of Agrieulture, entitled "Fighting the Corn Borer with Maehinery in the Two-Generation Area", eontains many suggestions and explanatory illustrations regarding plows and good methods of plowing, under corn-borer conditions.

BURNING INFESTED PLANTS

Burning is one of the effeetive methods of disposing of sueh infested eornstalks or other plant material as cannot be fed to livestock or plowed under eleanly. This method, however, may not be generally eonsidered a good farm praetiee from the standpoint of returning as mueh organie matter as possible to the soil. Nevertheless, if control is to be aehieved, the burning of cornstalks and other crop residues

infested with corn borers seems justified and must be adopted when the material cannot be effectively disposed of in any other manner. The method of burning infested plants may vary in accordance with the prevailing farm practice. In case the corn is cut and shocked the problem is comparatively simple, since any surplus shocks can be burned where they stand or, if necessary, hauled to a suitable location and burned, not later than May 15 of each year. This should include all cornstalks that have been used in building shelters for livestock, for thatching (fig. 29), windbreaks, or similar purposes, as well as surplus stalks stored for feeding purposes, and cornstalks along ditch banks and field borders.

In cases where the ears are husked from standing stalks the problem of burning the stalks completely becomes more difficult. The main point to keep in mind, however, is that all corn remnants should be fed, plowed under, or burned. If burning is considered the best solution of the problem, several methods of procedure are possible.

FIGURE 29.—Wire corncribs thatched with infested cornstalks. These stalks are a source of infestation unless disposed of by burning or otherwise before the moths emerge.

The stalks may be cut at or close to the ground level with any of the available types of stalk shavers, or with a short-handled heavy hoe in the case of small fields in which such a method is practicable. When dry, the stalks should be raked cleanly into windrows or piles and burned completely, even though it may be necessary to resort to hand methods in raking stalks into the fires.

Many types of regular farm equipment and special tools have been used to cut off standing cornstalks or other infested plants. One of the most effective devices perfected to date consists of a simple home-made sled-type stalk shaver (figs. 30 and 31). This stalk shaver is ideally adapted for slicing stalks or high stubble off at the ground surface preparatory to raking and burning. Repeated tests of this device under a wide variety of field conditions have given excellent results, and its use for this purpose is recommended. Directions for the construction of this stalk shaver at home for a small outlay of time and funds are given in Miscellaneous Publication 142 of the United States Department of Agriculture, entitled "Construction of Sled-Type Cornstalk Shavers."

In the operation of cleanly raking the cut-off cornstalks, high stubble, or other plant material into windrows, the best success to

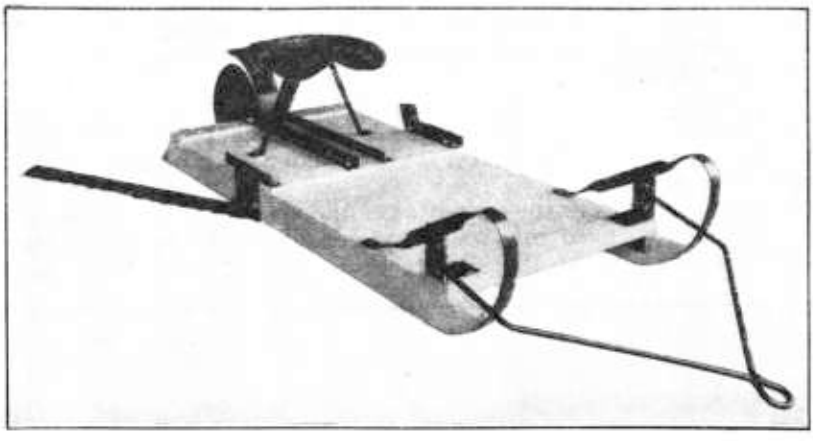

FIGURE 30.—A home-made stalk shaver for cutting off the stalks at the ground surface preparatory to raking and burning.

date has been obtained with side-delivery rakes (fig. 32). The most satisfactory side rake yet obtained has 4 instead of 3 tooth bars, carrying closely spaced teeth, the speed of the cylinder remaining

FIGURE 31.—Cutting 4 rows of cornstalks with 2 stalk shavers drawn by 3 horses.

normal. On fairly smooth ground this rake has performed a satisfactory job of raking, even with heavy cornstalks.

The common steel-toothed sulky dump rake can be used to rake trash into windrows preparatory to burning, provided that the soil surface is smooth, that the trash is fairly dry and clings together

without shattering, and that the operator does not attempt to gather too heavy a load before dumping. The special close-toothed sulky-dump rakes, now marketed by some manufacturers, do better work on smooth ground than rakes with the ordinary spacing of teeth. In raking cornstalks, however, the sulky-dump rake does not often rake cleanly enough to make plowing unnecessary.

Thus far the practice of hilling corn has proved a handicap in raking stalks cleanly. It is evident that the practice of level cultivation must be resorted to more freely if raking stalks is to be effective in corn-borer control.

In order to emphasize the importance of disposing of small pieces of trash on the surface of infested cornfields, it should be stated that careful examinations of the surface of typical infested fields have

FIGURE 32.—Raking infested cornstalks into windrows with a side-delivery rake, to be burned, is an effective method of corn-borer control if the infested stalks are cut at ground level, raked cleanly, and completely burned. This rake is a four-bar outfit with closely spaced teeth and shields. (Photo by Bureau of Agricultural Engineering.)

shown that, on an average, 14 percent of the total original borer population was found hidden in small pieces of cornstalks (fig. 25), corn husks, leaves, or weed stems that had been left on the ground after it had been improperly cleaned.

WINTER POLING IS NOT EFFECTIVE IN GENERAL PRACTICE

The practice of dragging sidewise a heavy log or railroad iron across the field to break off the stalks at the ground surface usually allows many of the stalks, though broken, to remain firmly attached, and this prevents a clean raking job. Experience has shown that only on rare occasions, when the stalks are frozen and when there is practically no snow on the field, can poling be done so efficiently as to allow clean raking. Therefore winter poling preparatory to burning is not recommended as a corn borer control measure, and some type of stalk shaver should be utilized as a means of detaching the cornstalks from the soil.

DISKING STUBBLE OR ENTIRE STALK FIELDS IS NOT EFFECTIVE

Disking cornstalks or high stubble (fig. 33) in preparation for seeding to small grain or other crops is a very objectionable practice from the standpoint of corn borer control, except when followed by clean plowing. Disking not only allows a very high percentage of borers to survive, but the shade subsequently furnished by the growing grain affords protection from the weather to the borers contained in the trash left on the soil surface.

Rolling, "cultipacking", disking, or other types of harrowing are all methods of practically no value in corn-borer control.

The present practice of direct disking of high stubble or cornstalks infested with the corn borer, as a preparation for small grains or other

FIGURE 33.—Typical field of high stubble. This practice of high cutting must be stopped in areas infested by the corn borer, unless such stubble is disposed of by clean plowing, or other means, before the moths emerge.

crops, must be discontinued if the pest is to be held in check and widespread commercial loss prevented. Disking should be preceded by the operations of cutting off the stalks at the ground level and completely disposing of them, together with all trash, by burning or otherwise.

CORN STUBBLE IS AN IMPORTANT SOURCE OF INFESTATION

It is plain that if the corn is to be cut, it should be cut as low and as early as possible and that all high-cut stubble should be disposed of by the recommended control methods.

The advisability of low cutting as a corn-borer control measure, in instances where the farm practice involves the cutting of corn, is further emphasized by the fact that less than 1 percent of the original borer population of the field is present in the underground portion of the corn stubble.

DESTROYING BORERS IN HOME GARDENS

In many localities of the two-generation area susceptible plants in many of the home gardens, especially small patches of sweet corn,

often contain more borers per plant than do the large commercial fields. In these gardens, susceptible vegetables, flowers, field crops, large weeds, and large-stemmed grasses growing in or along the margins of the sweet corn often contain many borers as a result of migration of the borers from corn, or from direct egg deposition by the corn-borer moths, or from both sources.

While these home gardens are usually small, the total acreage is sufficiently large to harbor large numbers of corn borers in many of the villages, suburbs, and cities in the older portion of the infested areas. Therefore, the clean-up of these home gardens becomes an important part of corn-borer control operations, especially in the two-generation area. The general procedure is quite similar to that described for large-scale control methods in the preceding pages. In brief, the infested host-plant residues, such as cornstalks or stubble, flower stalks, vegetable stalks, weeds, and grasses, may be fed to any livestock in the vicinity, plowed or spaded under, buried by hand, burned, or completely disposed of by any combination of such methods as is most convenient, preferably late in the fall.

CONTROL MEASURES THAT MAY BE USEFUL UNDER CERTAIN CONDITIONS

TIME OF PLANTING IN THE ONE-GENERATION AREA

In the Great Lakes section of the one-generation area, field and sweet corn planted late in April or in the first 3 weeks of May usually sustains the worst corn-borer infestation in a given locality. In contrast with this, plantings made the last week in May, or later, ordinarily suffer much less injury from the pest.

Experiences to date in the one-generation area, in localities where corn borers are numerous indicate that the avoidance of early planting, as judged by the usual planting program of the district involved, is an important help in avoiding severe injury by the pest.

However, recent field tests have shown that the smaller number of borers on later planted corn cause a much greater loss per borer than do those on the earlier planted corn. This greater damage per borer, plus the reduction in yield ordinarily suffered from late planting, offsets to a great extent any advantage gained from late planting.

TIME OF PLANTING IN THE TWO-GENERATION AREA

Under conditions where the pest multiplies twice each year, the late-planted corn, i. e., corn planted in June, is subject to attack by the second-generation borers and is most likely to be severely injured because of the large number of borers present at the susceptible stage. Corn planted very early may also be severely injured because of the concentration of first-generation borers on the comparatively small amount of food provided by early corn patches. Therefore, although a large proportion of the early-planted corn may escape serious injury, it is risky to plant corn very early in spots subject to severe infestation. There is a period between the two broods when corn is less subject to ovipositing moths. In the vicinity of Boston, Mass., early-season varieties of sweet corn planted from about May 15 to 25 have a good chance of escaping severe injury. South of Boston this best planting period will be somewhat earlier.

CHOICE OF CORN VARIETIES

None of the types, varieties, or strains of corn thus far tested under large-scale field conditions has shown any indication of real immunity from corn borer attack. There are indications, however, that some strains of corn possess inherent characteristics which enable them to resist or tolerate the attack of the borers better than other strains or varieties. The number of borers per plant at harvest as compared with the number of corn borer eggs originally on the plants is much smaller in some strains of corn than in others. Then again, varieties having either large or stiff stalks have shown a greater resistance to stalk breakage than varieties possessing small stalks, and lend themselves better to harvesting operations. It is hoped that strains of corn may eventually be bred which will possess a combination of many of these desirable characteristics.

TRAP CROPS

Attention has been called to the fact that the earliest planted fields of corn, particularly sweet corn, usually suffer the heaviest corn borer infestation in any given area. This naturally suggested the use of a small area of very early-planted sweet corn in fields intended for a main crop of field corn or late-planted sweet corn, to attract the corn-borer moths and thus act as a trap crop. Such trap crops *must be destroyed or used for fodder early in the season.* Actual attempts to apply the trap-crop method of control under field conditions, however, have failed to show reliable results from year to year. Trap crops cannot be depended on, but in a favorable season they attract many moths that would otherwise lay their eggs on the main crop of corn.

INEFFECTIVE CONTROL MEASURES

TRAP LIGHTS

One of the oldest and most ineffective methods used in attempting to control destructive insect pests was the trap light, the theory being that since some moths can be attracted to the light they may then be destroyed. Although extensive efforts and much money have been expended in attempts of this nature, the use of trap lights as a method of control has seldom been successful in the case of any insect pest. The trap-light method, in combination with various baits, however, was given a very thorough test in the course of the European corn-borer investigations. Repeated observations with many types, kinds, and colors of lights showed that the number of corn-borer moths attracted to such lights comprised less than 1 percent of the total number of corn-borer moths in the vicinity. It is plain, therefore, that this has no value as a method of corn-borer control.

ATTRACTIVE BAITS

Under experimental conditions corn-borer moths have been caught in traps baited with a 20-percent mollases solution in water, and while such a trap has proved useful for technical purposes, it is not recommended as an effective means of protecting corn or other crops susceptible to infestation by the corn borer.

CATERPILLARS OFTEN MISTAKEN FOR THE EUROPEAN CORN BORER

Several kinds of common native caterpillars, "worms", or borers are often mistaken for the European corn borer, and cause needless alarm. Some of these are similar in appearance to the European corn borer, and others, though very different in appearance, cause damage that often resembles the injury caused by the corn borer. Detailed descriptions and illustrations of many of these borers will be found in various Federal and State publications.

It is important that all corn growers outside the known infested area be on the look-out for the European corn borer. Therefore when any worms, caterpillars, or borers suspected of being the European corn borer are found, specimens should be placed in a tight glass vial containing dilute formalin or alcohol and sent to the corn-borer laboratory at 1920 Parkwood Avenue, Toledo, Ohio.

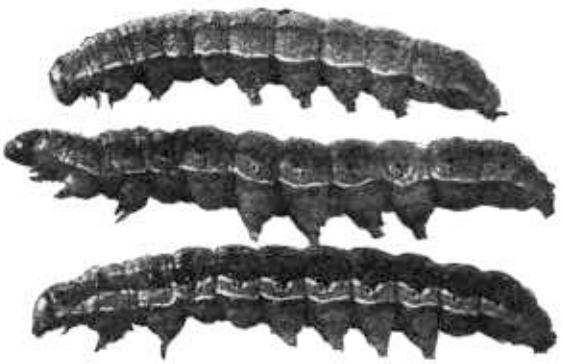

FIGURE 34.—Side view of three larvae of the corn ear worm showing the color types: Upper larva, green; middle one, rose colored; lower one, dark brown. Not quite twice natural size.

THE CORN EAR WORM

On account of the similarity of the damage it does to the ears of corn, the corn ear worm (*Heliothis obsoleta* Fab.) (fig. 34) is very often mistaken for the corn borer. This insect is also known as the cotton bollworm, tomato fruit worm, and tobacco bud worm.

The corn ear worm, however, is not a true boring insect and usually confines its damage to the silks and kernels of the ear, whereas the corn borer not only feeds habitually on the silks and kernels but also bores into the cob. Unlike the corn borer, the corn ear worm very rarely bores into the stalks, although if the ears have not developed on young plants it often feeds on the leaves and in the growing tip or "bud" of the plant. This injury sometimes results in broken-over tassels that at a distance resemble corn-borer damage, but close examination will show that these tassel stems have not been tunneled. This characteristic serves to distinguish such injury from that of the corn borer. Late in the winter and early in the spring corn ear worms are never present in the ears of corn or in the stalks, whereas corn borers may commonly be found in ears and stalks of corn at this time in areas in which corn borers are numerous.

The caterpillars of the corn ear worm are about 1½ inches long when full grown and vary greatly in color, ranging from tints of green, pink, rose, yellow, and brown to almost black. They may be beautifully striped, or spotted with brown, black, or yellow along the side and back, or they may be entirely free from stripes or spots. In appearance they can be readily distinguished from the corn borer by the fact that they are nearly twice the size of the latter. The

hairs arising from the black tubercles, or warts, on the back of the ear worm are much longer and stouter than those arising from the brown tubercles on the back of the corn borer. The castings of the ear worm are coarse, wet, and foul, while those of the corn borer are more finely divided and usually dry. The corn ear worm is widely distributed throughout the country.

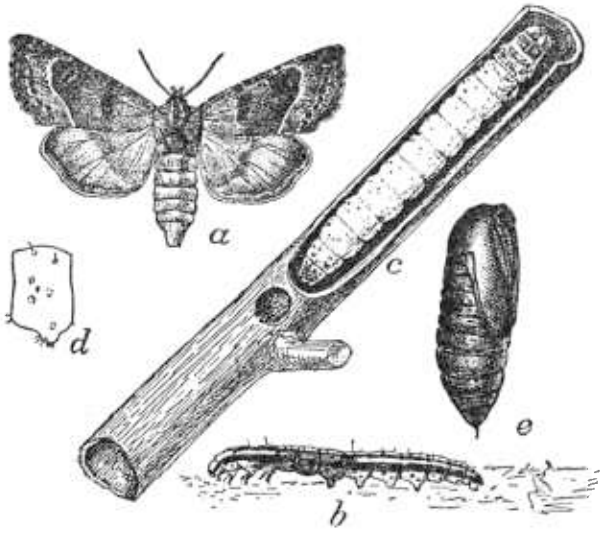

FIGURE 35.—The stalk borer: *a*, Female moth; *b*, half-grown larva or borer; *c*, full-grown larva in injured stalk; *d*, side view of segment of abdomen of full-grown larva; *e*, pupa. All somewhat enlarged.

THE STALK BORER

Stalk borers (*Papaipema nebris* Guen., form *nitela* Guen.) (fig. 35) are often very numerous during the early summer in some sections of the country. They work habitually within the growing tip (heart) and stalk of young corn, and are frequently mistaken for the European corn borer on account of their habit of boring into the cornstalks. They also bore into the stalks, and infrequently into the fruit, of several other cultivated crops and flowers and weeds.

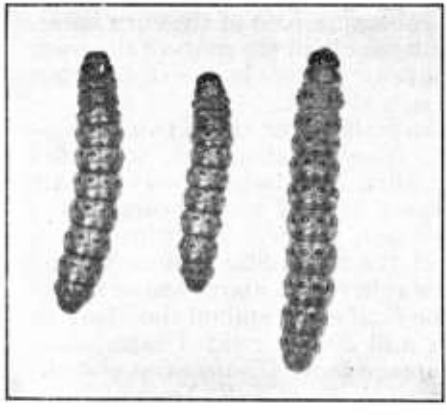

FIGURE 36.—The smartweed borer is very often mistaken for the European corn borer, as they are about the same size. The smartweed borer is found often in corn plants into which it has entered for shelter. Compare with figure 13. Twice natural size.

The young caterpillars of the stalk borer are very easy to distinguish from those of the corn borer, as they bear a dark-brown or purple band around the middle of the body, and several conspicuous brown or purple stripes run lengthwise of the body. The corn borer does not possess these conspicuous bands or stripes. As the stalk borer becomes full grown, however, these bands and stripes disappear, and the color becomes plain creamy white or light purple, and only inconspicuous markings are visible. The full-grown stalk borer is slightly more than an inch long and is much larger throughout than the corn borer. It is never found in cornstalks during the winter.

THE SMARTWEED BORER

The smartweed borer (*Pyrausta ainsliei* Heinr.) (fig. 36) is very frequently found in corn during the fall, winter, and spring. The appearance and work of this native borer resemble those of the European corn borer so closely that it is very difficult to distinguish between them. The smartweed borer usually feeds within the stems of smartweed (*Polygonum* spp.), but it commonly bores into the stalks of corn and other plants when seeking winter quarters. It is practically harmless to corn.

It is known to be very numerous throughout the eastern part of the country, and many reports of European corn borer occurrence have been due to the presence of the smartweed borer.

The caterpillars of the smartweed borer are about three-fourths of an inch long when full-grown, slightly smaller than the corn borer, and less robust. They are always slate-colored or gray when full grown, and in the living state they bear a very fine, faint line of darker color running along the middle of the back, whereas in the living corn borer this line is decidedly broader and very conspicuous. Except for these differences, and 1 or 2 microscopic distinctions discernible only by an entomologist, these two kinds of borers have the same appearance when full grown. On hatching from the eggs the small caterpillars of the corn borer have black heads, while those of the smartweed borer have pale amber-colored heads.

THE SOUTHERN CORN STALK BORER

In the Southern States, and especially in the South Atlantic States, the southern corn stalk borer (*Diatraea crambidoides* Grote) is a common enemy of the corn plant, and owing to its habit of tunneling in the stalks of corn it may be easily confused with the European corn borer. The southern corn stalk borer, however, does not bore into the ears of corn, whereas this habit is characteristic of the corn borer. This southern pest habitually overwinters only in the roots of the corn, whereas the European corn borer not only winters in the stubble but may also be found in the stalks and ears of corn.

The caterpillars of the southern corn stalk borer are of two types—a summer form and a winter form. The summer form, when full grown, is about 1 inch in length, with a dirty white body thickly dotted with round or irregular dark spots, each of which bears a short dark bristle. The head region is brownish yellow. The winter form differs from the summer form in that the caterpillar is more robust and is slightly shorter, while the spots referred to above are of nearly the same color as the body. Along the Gulf coast and on the Mexican border two distinct but very similar and closely related caterpillars may attack corn. These are the sugarcane borer (*Diatraea saccharalis* Fab.) and the southwestern corn borer (*D. grandiosella* Dyar).

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